AN-1373
APPLICATION NOTE

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ADA4530-1 Femtoampere Level Input Bias Current Measurement

by Vicky Wong

INTRODUCTION

The ADA4530-1 is a single, electrometer grade operational amplifier with a femtoampere (10^{-15}) level input bias current (I_B) and an ultralow offset voltage. Its ultralow input bias currents are production tested at 25°C and 125°C to ensure that the device meets its performance goals in a system application. Figure 1 and Figure 2 show the outstanding input bias current performance of the device over temperature and input common-mode voltage.

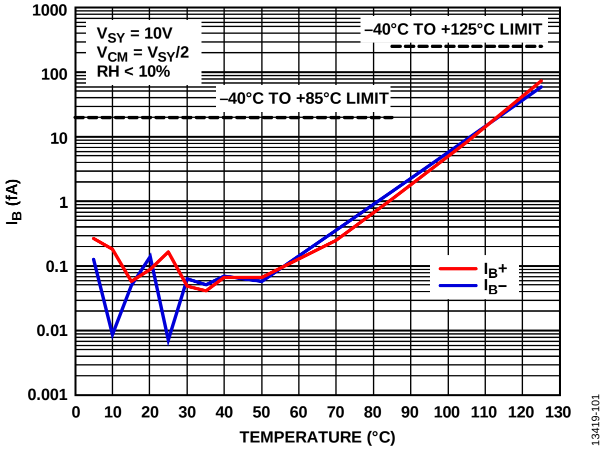

Figure 1. Input Bias Current (I_B) vs. Temperature

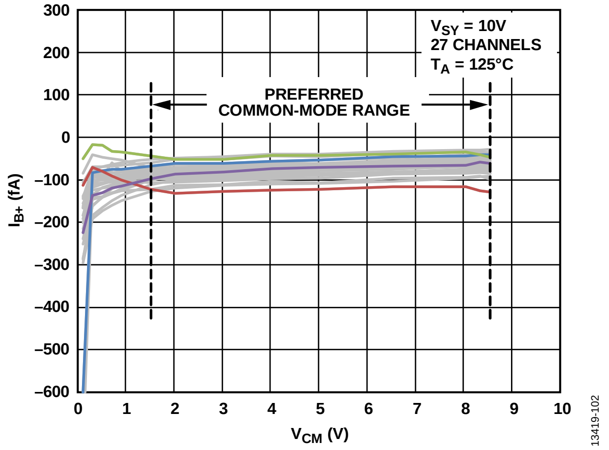

Figure 2. Noninverting Input Bias Current (I_{B+}) vs. Common-Mode Voltage (V_{CM})

The ADA4530-1 operates over the –40°C to +125°C industrial temperature range and is available in an 8-lead SOIC package. It is well suited for applications that require very low input bias current and low offset voltage, such as preamplifier for a wide variety of current output transducers (photodiodes, photomultiplier tubes), spectrometry, chromatography, and high impedance buffering for chemical sensors.

The ADA4530-1 has a unique pinout. The input and supply pins are placed on opposite sides of the package to prevent leakage. For ease of user design, the ADA4530-1 features an integrated guard buffer. The guard buffer drives the guard ring surrounding the input pins, thus minimizing both input pin leakage in a printed circuit board (PCB) design and board component count. The guard buffer output pins are also strategically placed next to the input pins to enable easy routing of the guard ring. For more information on guarding and physical implementation of guarding techniques, refer to the ADA4530-1 data sheet.

Low input bias current amplifiers are also typically available in T0-99 packages. These packages allow users to air wire the high impedance input pins or to use Teflon® insulator standoffs to prevent leakage current. These techniques increase manufacturing costs and are incompatible with modern automated PCB assembly processes. The surface-mounted, plastic package provided by the ADA4530-1 bypasses this legacy assembly approach and is reliable in a modern surface-mount manufacturing environment.

This application note highlights several different methods for measuring the ADA4530-1 femtoampere level input bias current feature in the SOIC package using the ADA4530-1R-EBZ-TIA or the ADA4530-1R-EBZ-BUF evaluation board.

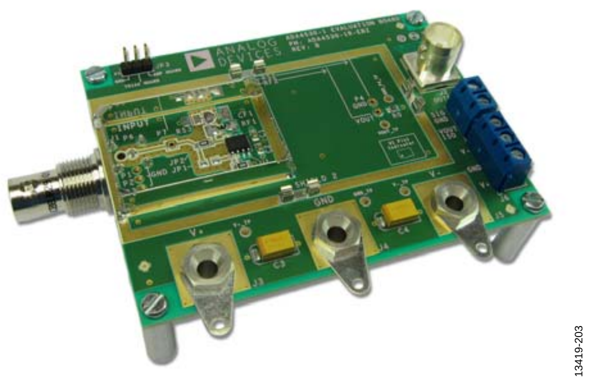

Figure 3. Photograph of the ADA4530-1R-EBZ-TIA

Figure 3 shows a photograph of the ADA4530-1R-EBZ-TIA. Note that hereafter, ADA4530-1R-EBZ refers to both the ADA4530-1R-EBZ-TIA and the ADA4530-1R-EBZ-BUF.

For full details on the ADA4530-1, see the ADA4530-1 data sheet. The ADA4530-1R-EBZ user guide (UG-865) should also be consulted in conjunction with this application note.

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REVISION HISTORY

10/15—Revision 0: Initial Version

CLEANING AND HANDLING

The input bias current measurement methods outlined in this application note use the ADA4530-1R-EBZ. Properly clean the ADA4530-1R-EBZ before each measurement to remove any contaminants, such as solder flux, saline moisture, dirt, or dust. This cleaning maintains the low leakage performance of the ADA4530-1R-EBZ.

An effective cleaning procedure follows:

1. Soak the ADA4530-1R-EBZ in an ultrasonic bath with cleanroom grade isopropyl alcohol for 15 minutes. Ultrasonic cleaning uses ultrasound at a high frequency, which creates cavitation in the cleaning solution. This process helps to remove contaminants on the surface of the ADA4530-1R-EBZ and in the areas under the soldered components that are hard to reach. The next cleaning steps require the use of fresh isopropyl alcohol.
2. Remove the ADA4530-1R-EBZ from the ultrasonic bath with a pair of forceps. Rinse and flush the ADA4530-1R-EBZ with isopropyl alcohol to remove any contaminant residue.
3. Flood the ADA4530-1R-EBZ with isopropyl alcohol and gently scrub it with an acid brush. Concentrate on the areas between the U1 pins, the input traces to J1, the guard ring, and the area within SHIELD1.
4. Rinse and flush the ADA4530-1R-EBZ again with isopropyl alcohol.
5. Repeat Step 3 and Step 4 for the bottom of the ADA4530-1R-EBZ.
6. Give a final flush of the top and the bottom of the ADA4530-1R-EBZ with isopropyl alcohol.
7. Use compressed dry air to dry the ADA4530-1R-EBZ. Blow air around the U1 pins, the input traces to J1, and the guard ring area. Direct the compressed air under J1 and U1 as well.
8. Bake the ADA4530-1R-EBZ in the temperature chamber at 125°C for 15 minutes to ensure that the ADA4530-1R-EBZ is completely dry.
9. After cleaning, place the covers on the metal shields. The metal shields also help to prevent any contact to the guarded area.

Always handle the ADA4530-1R-EBZ by the edges and never touch the area within SHIELD1 or SHIELD2.

MEASUREMENT TECHNIQUES

The ADA4530-1R-EBZ is available in two default configurations: the ADA4530-1R-EBZ-BUF, which is the device under test (DUT) in buffer mode, and the ADA4530-1R-EBZ-TIA, which is the DUT in transimpedance mode.

Metal shields on the ADA4530-1R-EBZ prevent capacitive coupling from external interference. The shields also prevent contact to the guarded area and therefore prevent contamination from fingerprints or dust to the high impedance inputs. The ADA4530-1R-EBZ-BUF and the ADA4530-1R-EBZ-TIA each have two 1.0 in × 1.5 in × 0.25 in metal shields preassembled on the top (SHIELD1) and bottom (SHIELD3) of the board. In addition, a larger 1.5 in × 3 in × 0.75 in metal shield (SHIELD2) is provided separately with each evaluation board. Metal clips are assembled on each board to hold SHIELD2 in place. The guard buffer drives these shields to the DUT noninverting pin potential.

To provide an even more robust electrostatic shielding, shield the ADA4530-1R-EBZ with a metal box when evaluating the input bias current. This box within a box construction is effective because the outer shield is driven to ground and the inner shield is driven with guard. For more information on guarding and shielding, refer to the ADA4530-1 data sheet.

The ADA4530-1R-EBZ is also preassembled with a 499 Ω output resistor, which isolates any output load from the amplifier output and prevents oscillation from excessive capacitive loading.

Throughout this application note, I_{B+} refers to the input bias current flowing through the DUT noninverting pin and I_{B-} refers to the input bias current flowing through the DUT inverting pin. I_B refers to both I_{B+} and I_{B-}.

The next three sections describe the different input bias current measurement methods that can be implemented on the ADA4530-1R-EBZ.

KEITHLEY 6430 MEASUREMENT

The typical input bias current of the ADA4530-1 at 25°C is <1 fA, and this ultralow current is impossible to measure accurately with any available meter. For example, the offset current of a Keithley 6430 SourceMeter® at a 1 pA range is already limited to 7 fA. Therefore, to measure I_B, it is necessary to heat the DUT to increase the input bias current to a measurable value. At 125°C, I_B is measurable with a maximum of ±250 fA, per the data sheet specifications.

For the purpose of I_{B+} testing, the ADA4530-1R-EBZ-BUF is placed in a temperature chamber. To measure I_{B+}, connect the ADA4530-1 noninverting pin (through J1) directly to the Keithley 6430 SourceMeter with a triax cable. For more information about triax cabling, refer to the ADA4530-1 data sheet.

See Figure 4 for a simplified schematic and Figure 5 for the SourceMeter used.

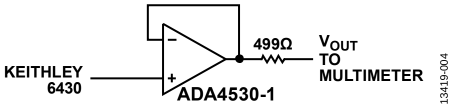

Figure 4. Simplified Schematic for I_{B+} Measurement with the Keithley 6430 SourceMeter

Figure 5. Keithley 6430 SourceMeter

The procedures for measurement test setup follow:

1. Use the ADA4530-1R-EBZ-BUF. Ensure that SHIELD1 and SHIELD3 are closed.
2. Place the ADA4530-1R-EBZ-BUF in a metal box (see Figure 6).
3. Cover the metal box and place the ADA4530-1R-EBZ-BUF in a temperature chamber.
4. Connect the input triax connector (J1) to the IN/OUT port of the Keithley 6430 Remote PreAmp via a triax cable that can withstand up to 125°C. Many triax cables are only functional up to 85°C. A 125°C triax cable can be built using Harbour Industries M17/131-RG403 TRX cable and a Model 5218 triax connector from Pomona Electronics.
5. Set the temperature chamber to 125°C. Do not place the Keithley 6430 Remote PreAmp or SourceMeter in the temperature chamber.
6. After the temperature chamber has reached 125°C, allow the evaluation board to soak for an hour.

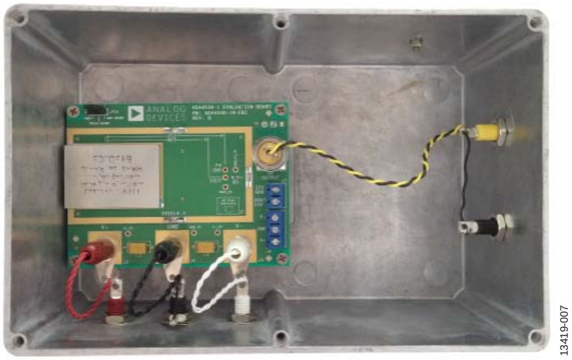

Figure 6. Metal Box (Connected to Signal Ground) Enclosing the ADA4530-1R-EBZ-BUF

Test procedures for measuring I_{B+} for the ADA4530-1 using the Keithley 6430 SourceMeter follow:

1. Provide supplies to the ADA4530-1R-EBZ-BUF:
   a. V+ (J3): 5 V
   b. GND (J4): 0 V
   c. V− (J5): −5 V
2. Provide the test setup for the Keithley 6430 SourceMeter:
   a. Auto range: off
   b. Source voltage (V): 0 V
   c. Measure current (I): set the current range to 1 pA
   d. Number of power line cycles (NPLC): 1 (normal speed)
   e. Filter: auto
3. Log the measurement data for 300 seconds at 1 sample per second (SPS) and calculate the average I_{B+}. Note that longer measurement periods yield more accurate averaging. The average I_{B+} should be less than 100 fA.

Figure 7 shows data collected from the measurement of one typical DUT for 5000 seconds. The average measured I_{B+} is approximately 11 fA to 12 fA at 125°C. Typical input bias current at 125°C varies from device to device. Expect most DUTs to measure less than 100 fA with the ADA4530-1R-EBZ-BUF.

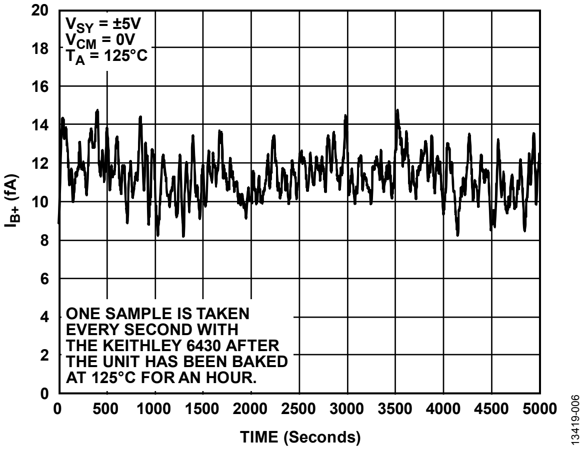

Figure 7. Noninverting Input Bias Current (I_{B+}) vs. Time

CAPACITIVE INTEGRATION MEASUREMENT

Current flowing through a capacitor (I_C) can be calculated using the capacitance value (C) and the measured change in output voltage across the capacitor over time (dV_C/dt) with the following equation:

$$I_C = \frac{C\,dV_C}{dt}$$

This relationship can be used to calculate I_{B+} based on the rate at which it charges the DUT input capacitance. Observe this charging of the input capacitance by measuring the output of the DUT in buffer configuration with the noninverting input unconnected.

To calculate I_{B+}, use the following equation:

$$I_{B+} = \frac{C_P\,dV_{OUT}}{dt}$$

where:
C_P is the input capacitance.
dV_{OUT}/dt is the change in amplifier output voltage over time.

Figure 8 shows a simplified schematic of the capacitive integration method.

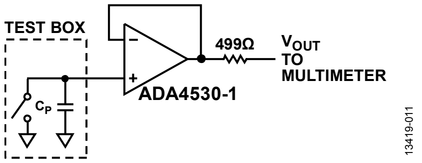

Figure 8. Simplified Schematic of the Capacitive Integration Method

As with the measurement method described in the Keithley 6430 Measurement section, place the ADA4530-1R-EBZ-BUF in a temperature chamber. Access the noninverting input of the DUT using a triax cable/connector connected to a test box outside of the temperature chamber (see Figure 9). The test box consists of a triax connector with access to the noninverting input signal, guard, and signal ground potential (see Figure 10). It provides the means to short the noninverting input pin of the DUT to ground outside the temperature chamber.

Figure 9. Capacitive Integration Measurement Method

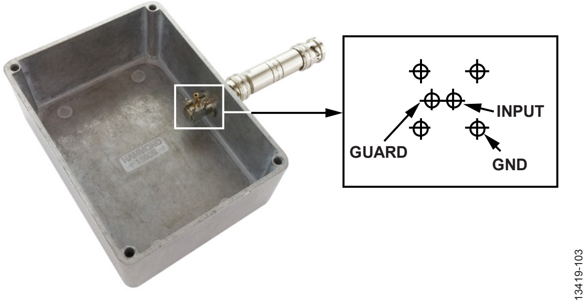

Figure 10. Test Box and Triax Connector

To calculate input bias current from the output voltage ramp rate of the DUT, the input capacitance value must be known. Therefore, the total input capacitance (C_P), which consists of the capacitance of the DUT, the board, the traces, and the triax cable/connector, must be measured. However, the input capacitance is very low and difficult to measure. Two recommended methods for cross checking the value of C_P are using an input series resistor and using an input test capacitor.

Measuring Total Input Capacitance with an Input Series Resistor

This method calculates the total input capacitance by measuring the frequency of the pole created from the interaction between a known resistance and the input capacitance.

Measurement guidelines follow:

1. Use the ADA4530-1R-EBZ-BUF. Short the triax guard to the amplifier guard on the ADA4530-1R-EBZ-BUF using JP3.
2. Place the ADA4530-1R-EBZ-BUF in a metal box. Connect the ADA4530-1R-EBZ-BUF to the test box with a triax cable/ connector (see Figure 9).
3. Connect a function generator to the input pin of the test box through an input series resistor, R_S, and an oscilloscope to the output of the ADA4530-1R-EBZ-BUF (see Figure 11).
4. Short the input series resistor, R_S.
5. Using the function generator, apply a 1 kHz, 1 V p-p input sine wave.
6. Use the oscilloscope to check that $V_{OUT} = V_{IN}$.
7. Remove the short across R_S. An 8 MΩ resistor is used for R_S. To reduce stray capacitance, use multiple resistors in series instead of one large resistor. In this case, four 2 MΩ resistors are soldered in series.
8. Slowly increase the input signal frequency until the output drops by a factor of √2. At this frequency, the input signal frequency at the −3 dB point is

$$f_{-3dB} = \frac{1}{2 \times \pi \times R_S \times C_P}$$

Hence,

$$C_P = \frac{1}{2 \times \pi \times R_S \times f_{-3dB}}$$

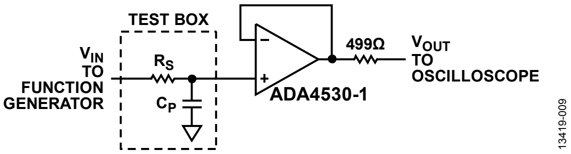

Figure 11. Measuring Total Input Capacitance with an Input Series Resistor

Measuring Total Input Capacitance with an Input Test Capacitor

This method calculates the total input capacitance by measuring the attenuation of an input voltage using a voltage divider created from the input capacitance and a known capacitance.

Measurement guidelines follow:

1. Use the ADA4530-1R-EBZ-BUF. Short the triax guard to the amplifier guard on the ADA4530-1R-EBZ-BUF using JP3.
2. Place the ADA4530-1R-EBZ-BUF in a metal box. Connect the ADA4530-1R-EBZ-BUF to the test box with a triax cable/ connector (See Figure 9).
3. Place a capacitor with a known value, C_{TEST}, at the input pin. A 10 pF test capacitor is used. Connect a function generator to the input pin of the test box through C_{TEST} and an oscilloscope to the output of the ADA4530-1R-EBZ-BUF. See Figure 12.
4. Using a function generator, apply a 1 kHz, 1 V p-p input sine wave.
5. Using the oscilloscope, measure the peak-to-peak output voltage.
6. The input/output transfer function is as follows:

$$\frac{V_{OUT}}{V_{IN}} = \frac{C_{TEST}}{C_P + C_{TEST}}$$

Hence,

$$C_P = \frac{C_{TEST}(V_{IN} - V_{OUT})}{V_{OUT}}$$

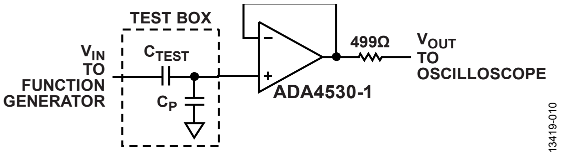

Figure 12. Measuring Total Input Capacitance with an Input Test Capacitor

Measuring I_{B+} with Known Input Capacitance

On average, the two input capacitance measurement methods yield a measured input parasitic capacitance of about 2 pF for the ADA4530-1R-EBZ-BUF. Note that this capacitance value is less than the amplifier specification on the data sheet and low considering the length of triax cable used. The internal guard buffer bootstraps most of the physical capacitances, which greatly reduces the effective input capacitance value.

With the known input capacitance, the output voltage ramp rate of the DUT can be measured to calculate I_{B+}.

See Figure 8 for the simplified schematic of this capacitive integration method.

The procedures for test measurement setup follow:

1. Use the ADA4530-1R-EBZ-BUF. Ensure that SHIELD1 and SHIELD3 are closed.
2. Short the triax guard to the amplifier guard on the ADA4530-1R-EBZ-BUF using JP3.
3. Place the ADA4530-1R-EBZ-BUF in a metal box (see Figure 9).
4. Place the metal box containing the ADA4530-1R-EBZ-BUF in the temperature chamber.
5. Connect the input triax connector (J1) to the test box (see Figure 8). Use a triax cable that can withstand up to 125°C. Many triax cables are only functional up to 85°C. A 125°C triax cable can be built using the Harbour Industries M17/131-RG403 TRX cable and the Model 5218 triax connector from Pomona Electronics.
6. Connect the output of the board to a multimeter via the output BNC connector or the output terminal block. In the lab, a 5.5 digit to 6.5 digit multimeter that supports data logging was used.
7. Set the temperature chamber to 125°C.
8. After the temperature chamber has reached 125°C, allow the ADA4530-1R-EBZ-BUF to soak for an hour.

Test procedures for measuring the I_{B+} of the ADA4530-1 with the capacitive integration measurement method follow:

1. Provide the following supplies to the ADA4530-1R-EBZ-BUF:
   a. V+ (J3): 5 V
   b. GND (J4): 0 V
   c. V− (J5): −5 V
2. Provide the test setup for the Keithley 2000:
   a. Auto range: off
   b. Custom range: 10 V
   c. Time delay: 1 msec
   d. Measurement delay: 1 sec
   e. NPLC: 1 (normal speed)
3. Using the test box, short the DUT noninverting input to signal ground for approximately 10 seconds.
4. Remove the short to ground and leave the noninverting pin unconnected.
5. Capacitive current (I_{CAP}) flowing across the input capacitance appears as a change in the DUT output voltage.
6. Log the output voltage with the multimeter for 300 seconds at 1 SPS.

Figure 13 and Figure 14 show the board output voltage vs. time and the capacitive current vs. time, respectively.

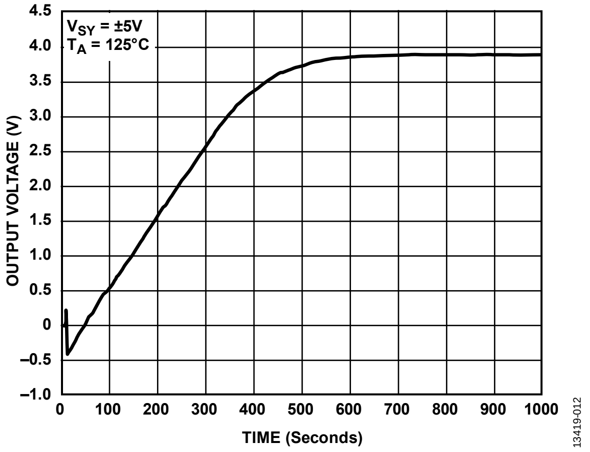

Figure 13. Output Voltage vs. Time

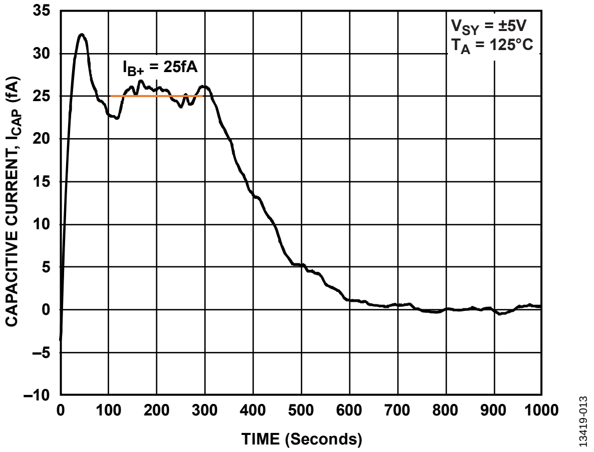

Figure 14. Capacitive Current vs. Time

See Figure 13. From 0 seconds to 10 seconds, the noninverting input is shorted to ground. The output voltage thus measures close to 0 V for the first 10 seconds. When the noninverting input is disconnected from ground, the output voltage changes abruptly. Because this is a manual disconnect, any vibration or charges from the fingers can be coupled into the input and cause output voltage spikes, as seen at time = 10 seconds. Relays are not used to short and open the input pin because of their low insulation resistance. A relay with low insulation resistance effectively decreases the total resistance as seen at the noninverting input, compromising measurement accuracy. Refer to the ADA4530-1 data sheet for more information on insulation resistance.

Immediately after the noninverting input is left unconnected, the input bias current (I_{B+}) flows through the input parasitic capacitance, causing a change in the output voltage. Measure the capacitive current right after the noninverting pin is disconnected from ground (see Figure 14) because during this short time period, the capacitive current (I_{CAP}) is a much closer value to I_{B+}. As the noninverting input voltage increases in magnitude, leakage current through the parasitic resistance (I_{RES}) on the board becomes significant; therefore, the change of output voltage is a function of both I_{RES} and I_{CAP} (see Figure 15).

In addition, the input bias current is not constant over the input common-mode voltage range (see the input bias current vs input common-mode voltage graphs in the ADA4530-1 data sheet). This variation can account for the changing slope of integration (see Figure 14). The output voltage stops ramping (see Figure 13) when the input bias current equals the input common-mode voltage divided by R_P. This condition tends to happen outside the input common-mode voltage range when input bias current is close to zero.

Note that at lower temperatures, the ADA4530-1 has an ultralow level of input bias current and that dielectric relaxation is an additional error limiting the accuracy of this method. These dielectric relaxation currents can be larger than the actual bias currents. Therefore, measurement using this method is performed at the elevated temperature of 125°C where the input bias current dominates over dielectric effects. Refer to the ADA4530-1 data sheet for more details on dielectric relaxation.

With the capacitive integration method, the input bias current at 125°C measures less than 100 fA.

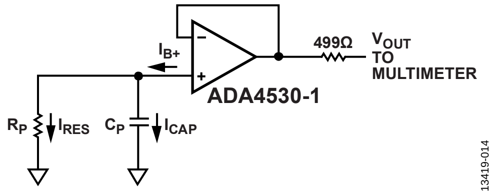

Figure 15. Board Input Parasitic Capacitance Used to Measure Input Bias Current

ΔV_{OUT} (TWO TEST OUTPUT VOLTAGE) MEASUREMENT

The first two measurement methods discussed in this application note require heating the evaluation board to 125°C to increase the input bias current to a measureable level. This ΔV_{OUT} measurement method allows user to measure I_{B+} (or I_{B-}) at room temperature without a temperature chamber.

This ΔV_{OUT} method requires two tests to measure the input bias current. The first test measures V_{OUT1}, which corresponds to the baseline offset voltage of the ADA4530-1R-EBZ. The second test measures V_{OUT2}, which is the sum of the baseline offset voltage and the voltage drop created by I_{B-} or I_{B+} flowing through the feedback or input series resistor.

Use the ADA4530-1R-EBZ-TIA for I_{B-} measurement and the ADA4530-1R-EBZ-BUF for I_{B+} measurement.

I_{B-} *Measurement*

Figure 16 shows a schematic for measuring I_{B-} using the ADA4530-1R-EBZ-TIA. The DUT is configured in a transimpedance configuration, and the output voltage is measured and logged using an 8.5 digit multimeter, the Keysight 3458A. Use a large value feedback resistor on the order of gigaohms (GΩ) or teraohms (TΩ) to obtain a measureable output voltage; for example, the ADA4530-1 was characterized using a 1 TΩ (TΩ = 10^{12} Ω) resistor, which provides 1 mV per fA of sensitivity.

The ADA4530-1R-EBZ-TIA comes assembled with a 10 GΩ SMT resistor at R_{F1}. The feedback resistor converts I_{B-} to an output voltage (V_{OUT}), where

$$V_{OUT} = I_{B-} \times Feedback\ Resistor$$

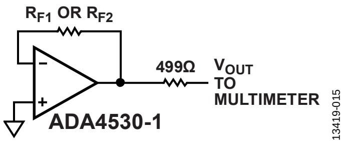

Figure 16. I_{B-} *Measurement Schematic*

First, establish the baseline offset voltage of the ADA4530-1R-EBZ-TIA by shorting out the feedback resistor and measuring the output voltage (V_{OUT1}) of the DUT in a buffer configuration. Then, remove the short and measure the output voltage with the feedback resistor in place.

The feedback resistor converts I_{B-} to a measureable output voltage. V_{OUT2} is the sum of the baseline offset voltage and the voltage drop created by I_{B-} flowing through the feedback resistor.

Calculate I_{B-} by

$$I_{B-} = \frac{(V_{OUT2} - V_{OUT1})}{Feedback\ Resistor}$$

The procedures for test measurement setup follow:

1. Use the ADA4530-1R-EBZ-TIA.
2. Remove the SHIELD1 cover. Short the feedback resistor (R_{F1}) using the P7 and VOUT pin sockets.
3. Place the ADA4530-1R-EBZ-TIA in a metal box.
4. Connect the output of the ADA4530-1R-EBZ-TIA to the Keysight 3458A multimeter.

Step by step test procedures for measuring I_{B-} follow:

1. Provide supplies to the ADA4530-1R-EBZ-TIA:
   a. V+ (J3): +5 V
   b. GND (J4): 0 V
   c. V− (J5): −5 V
2. Provide the test set up for the Agilent 3458A.
   a. Auto range: off
   b. Manual range: 0.1 V
   c. NPLC: 10
3. Measure the output voltage. Log the results and calculate the average output voltage (V_{OUT1}). Note that longer measurement periods yield more accurate averaging. A test length of at least 60 seconds accommodates for any warm up effects.
4. Turn off the supplies to the ADA4530-1R-EBZ-TIA.
5. Remove the short. By default, expect the amplifier to be in a transimpedance configuration with a 10 GΩ feedback resistor at R_{F1}.
6. Place the cover on SHIELD1.
7. Measure the output voltage (a sum of the offset voltage of the board and the voltage drop due to I_{B-} flowing through the feedback resistor). Log the results and calculate the average output voltage (V_{OUT2}). Suggested test length is 300 seconds. Averaging lowers the resistor noise. A 10 GΩ resistor has about 12.8 μV/√Hz of thermal noise. With 300 seconds of data, total integrated resistor noise is about 6 μV p-p. This is equivalent to approximately 0.6 fA of measurement inaccuracy. More averages provide diminishing returns due to the increase in low frequency 1/f noise.
8. Calculate the input bias current by

   $$I_{B-} = \frac{V_{OUT2} - V_{OUT1}}{10\ \text{G}\Omega}$$

9. The equation in Step 8 assumes that the feedback resistance value is accurately known. Verify this assumption by forcing a known test current into the ADA4530-1R-EBZ-TIA and measuring the output voltage. The Keithley 6430 SourceMeter was used to source 250 pA into the inverting pin of the DUT via J1. The output should read approximately

   250 pA × 10 GΩ = 2.5 V

   Any deviation in output voltage from the expected value is due to the tolerance of the feedback resistor. The preassembled 10 GΩ resistor, R_{F1}, has a 10% tolerance.

Figure 17 and Figure 18 show V_{OUT1} and V_{OUT2} for a sample unit over a 300 second interval and their associated average values. Figure 19 shows the calculated I_{B-}. Figure 20 shows the average measured feedback resistance value, R_{F1}. The resistance value is within its 10% tolerance.

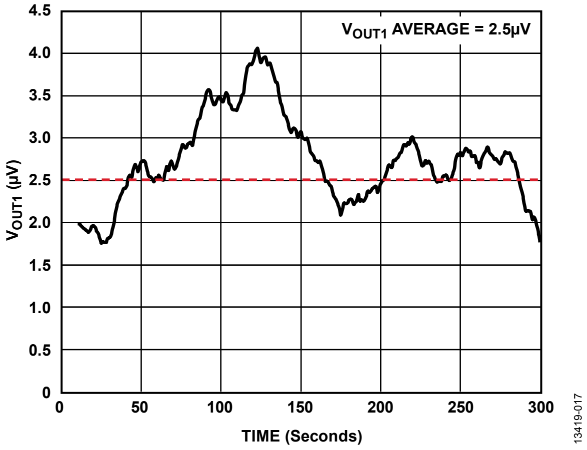

Figure 17. V_{OUT1} vs Time

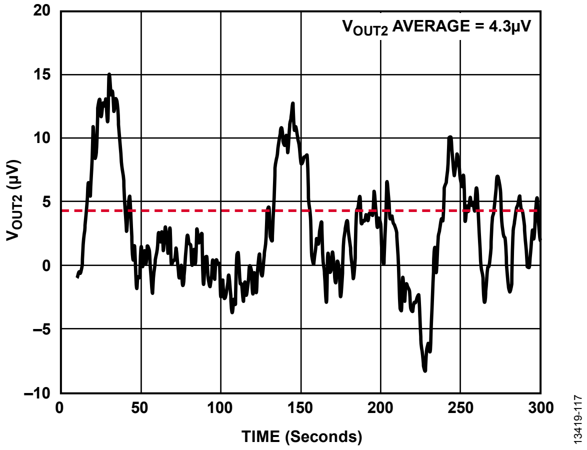

Figure 18. V_{OUT2} vs Time

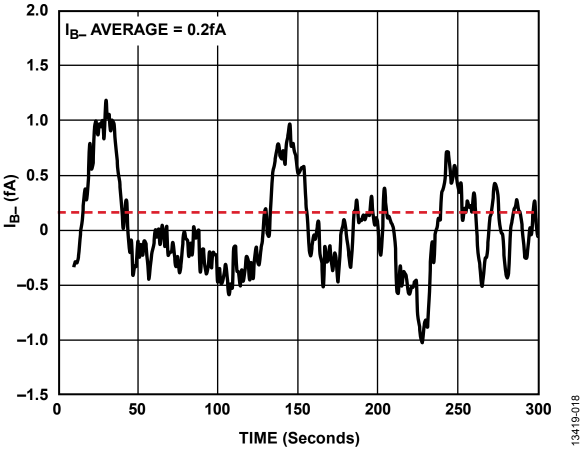

Figure 19. I_{B-} vs Time

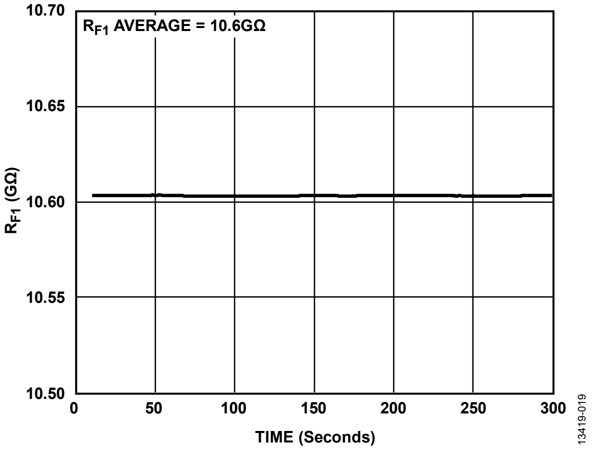

Figure 20. Measured Feedback Resistance (R_{F1}) vs Time

This measurement method can also be performed with larger value feedback resistors. These large value resistors are often glass encapsulated, hermetically sealed, and come in large footprints. Using a higher value feedback resistor yields a better signal-to-noise ratio at the output and a more accurate measurement. The ADA4530-1R-EBZ-TIA provides pin sockets that allow the use of through-hole resistors (R_{F2}) such as the Ohmite RX-1M ultrahigh resistance, high stability, hermetically sealed resistor. When using these large value through-hole resistors, remove R_{F1}, which is preassembled on the ADA4530-1R-EBZ-TIA. After the rework, clean the ADA4530-1R-EBZ-TIA according to the instructions in the Cleaning and Handling section before taking any measurement. Insert the large through-hole resistor between the P7 and VOUT pin sockets and measure I_{B-} by repeating the same steps outlined in this section. Change the magnitude of current being sourced into the DUT in Step 9 accordingly.

I_{B+} Measurement

Use the ADA4530-1R-EBZ-BUF for I_{B+} measurement. This measurement method is similar to the measurement method outlined in the I_{B-} Measurement section. See Figure 21 for the I_{B+} measurement schematic. The input series resistor converts I_{B+} to an output voltage (V_{OUT}) at J2, where:

$$V_{OUT} = I_{B+} \times Input\ Series\ Resistor$$

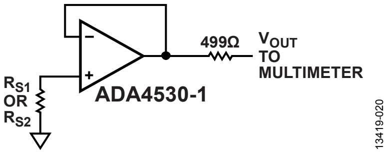

Figure 21. I_{B+} Measurement Schematic

Establish the baseline offset voltage of the ADA4530-1R-EBZ-TIA by shorting the DUT noninverting pin to ground. To do this, connect a wire from the P7 to P4 (GND) pin sockets. The baseline offset voltage is V_{OUT1}. Remove the short and measure the output voltage with the input series resistor in place. Users can assemble a 1206 or 1210 package size SMT resistor at R_{S1} or use a large through-hole resistor from the P7 to P4 (GND) pin sockets. The input series resistor converts the I_{B+} to a measureable output voltage. V_{OUT2} is the sum of the baseline offset voltage and the voltage drop created by I_{B+} flowing through the input series resistor. Calculate I_{B+} by

$$I_{B+} = \frac{V_{OUT2} - V_{OUT1}}{Input\ Series\ Resistor}$$

CONCLUSION

The ADA4530-1 is an electrometer grade amplifier with a femtoampere level input bias current. This application note details three methods for measuring the femtoampere level input bias current: Keithley 6430 measurement, capacitive integration measurement, and ΔV_{OUT} (two test output voltage) measurement.

- The Keithley 6430 measurement method is a direct measurement of I_{B+} using the Keithley 6430 SourceMeter. This test method uses only a calibrated instrument for input bias current measurement. However, because the DUT input bias current is extremely low (<1 fA), it is impossible to measure I_B accurately at room temperature. The DUT must be heated to increase I_B to a measureable value. This method thus requires a temperature chamber, a triax cable rated up to 125°C, and the Keithley 6430 SourceMeter. Therefore, the setup cost is high in return for a simple direct measurement.
- The capacitive integration method calculates I_B by measuring the change in amplifier output voltage over time with a known input capacitance. This measurement can be performed without a high-end source measurement unit (SMU) and only requires a multimeter to monitor the output voltage; however, the setup time is long. To calculate the input bias current, the total input capacitance value must be known. Therefore, the input capacitance must be measured before the integration test. This measurement method involves disconnecting wires by hand to avoid using relays with low insulation resistance and requires a temperature chamber to heat the DUT to increase I_B to a measurable level. In addition, I_B is not constant over input common-mode voltage. There is also only a short period of time during which I_B can be calculated from the capacitive integration measurement method.
- The ΔV_{OUT} (two test output voltage) measurement method requires two tests to measure input bias current. The first test measures V_{OUT1}, which corresponds to the baseline offset voltage of the ADA4530-1R-EBZ. The second test measures V_{OUT2}, which is the sum of the baseline offset voltage and the voltage drop created by I_{B-} or I_{B+} flowing through the feedback or input series resistor. The setup is fast and the cost is low. The ADA4530-1R-EBZ-TIA is preassembled with a 10 GΩ resistor, and measurement can be taken with a multimeter. However, for a more accurate measurement, a user can opt to use a larger value feedback or input series resistor. These large value resistors are often glass encapsulated and hermetically sealed, allowing them to achieve a high degree of accuracy and stability. In return, their costs are typically high. These resistors also require extraordinary cleanliness and special cleaning procedures, and they must be handled only by the terminals to avoid contamination.

For more information on the ADA4530-1, refer to the ADA4530-1 data sheet and the ADA4530-1R-EBZ user guide, UG-865.

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